color for a comparatively long time, and beside this the colors which flash out and disappear immediately. A very interesting fact struck me with regard to the latter class. It is generally known that an auroral arch is often composed of a series of spear-like shafts of light arranged perpendicularly to the direction of the arch, which appear to be in constant motion. A number of these spears will suddenly become brilliant and the lower ends shoot out of the arch into the black sky below. The brilliancy will then run along the arch like a wave of light, lighting up all the spears as it goes along. I noticed that the "front" of such a wave of brilliancy and the points of the spears *when shooting out* were bright red, but as soon as the motion stopped the color disappeared, while the more violent the motion the purer and brighter the red. It appeared as if some physical process accompanied the passage of the auroral beam through the air and gave out a red light. For example, if the air had to be ionized before the discharge could pass through, then the process of ionization produced red light. If the motion was particularly violent, the production of red light would be followed by a production of brilliant green light, so that if a bright wave passed along an arch two waves of color would appear to travel along, first a wave of red light, closely followed by a green wave, the two traveling so closely together as to appear as one wave having a two-colored crest. Similarly spears shooting out with a great velocity would appear to have red and green tips.

The question of the relation of clouds to auroras has been very often raised. Three of my observations bear on this point.

On the evening of October 11, 1903, after a fairly active display, the aurora disappeared; but its place was taken by a system of narrow bands of cirrus clouds stretching right across the sky, which, being illuminated by the bright moon, had all the appearance of the aurora. That they did not form part of the aurora could only be decided at first owing to no line appearing in the spectroscope when pointed at them; but later there could be no doubt, as they partly obscured the moon.

On October 26 a very similar phenomenon again appeared; that which at first was taken to be aurora, later turned out to be cloud.

On December 13 the most brilliant auroral display of my stay took place. The whole display reached a climax at 9:45, when a most brilliantly colored corona shot out from the zenith. While this final brilliant display was taking place the sky suddenly became thinly overcast, and the aurora was only visible later as bright patches through the clouds.

It has long been a matter of controversy as to whether the aurora ever extends into the lower legions of the atmosphere. Several observers positively affirm that they have seen it quite close to the ground. This may be due to an optical illusion. One evening I was, for a considerable time, in doubt as to whether the aurora was really under the clouds or not. All over the sky were detached clouds, the clouds being of about the same size and shape as the spaces between them. Right across the sky a long narrow auroral beam stretched, showing bright and dark patches owing to the clouds. It looked exactly as if the auroral beam ran along under the clouds brightly illuminating the patches of cloud which it met. In reality the bright patches were the openings and not the clouds. It took me a long time to make quite certain of this, and it was only by at last seeing a star in the middle of a bright patch that I could be quite certain.

Lemström strongly supported the idea that the aurora often penetrates down to the earth's surface, and described how on one occasion the auroral line appeared in a spectroscope pointed at a black cloth only one or two meters away. I was able to repeat this observation on several occasions, and found that the line which then appeared in the spectroscope was not due to an auroral discharge in the air between the spectroscope and the black cloth, but was due to reflected light, which it was impossible to prevent entering the spectroscope, as the whole landscape was lit up with the monochromatic light of the aurora.

All the time I observed the aurora I could not detect the slightest noise accompanying the discharge.

THE TIME OF MOONRISE AND MOONSET.[1]

By WM. F. RIGGE, S. J., Creighton University, Omaha, Nebr.

On account of the moon's rapid motion both in right ascension and in declination, the computation of the times of the moon's rising and setting is apt to prove very laborious, since it can not be done except by successive approximations. The object of this article is to explain a very rapid method to be used for this purpose. While it may be an old one, the writer's reason for presenting it is that he has never found it in print.

The method to be described is a graphic one and requires in advance the construction of three diagrams, which we may denote A, B, and C. In order to show their practical use, they have been prepared for Omaha, Nebr. The problem before us, therefore, is to find the central [standard] times of moonrise and moonset at Omaha.

1. The first thing to be done is to find the time of the moon's meridian passage. This is given for Greenwich on page IV of every month in the American Ephemeris.[2] To reduce it to Omaha and to central time, we must add to it 6.4 (the Greenwich longitude of Omaha being $+ 6^h 23.8^m$) times the hourly difference there given, plus 23.8 minutes. This is done rapidly by means of diagram A, whose construction needs no explanation. Thus for January 13, 1906, when the time of the moon's transit over the meridian of Greenwich is $14^h 58.4^m$ and the hourly difference is 2.13^m, we find that 2.13 on diagram A indicates something over 37 minutes, which added to the Greenwich time gives $15^h 36^m$ as the central time of the moon's transit at Omaha.

2. The next step is to find the moon's hour angle. This is shown on diagram B for Omaha, the latitude being $+ 41° 16'$. The formula

$$\cos \tau = - \tan \varphi \tan \delta$$

gives the true hour angle, which must be corrected for refraction and parallax. For purpose of prediction it is evident that only the mean refraction or 36′ can be taken. Special computation will show that this diminishes the hour angle by 3.1^m for all values of δ between plus and minus 30°. For the parallax the mean value of 57.6′

[1] Many of the Weather Bureau observers, when called into court to testify as to the state of the weather at a given time, are asked whether the moon had risen, and they have, therefore, requested the Central Office to furnish them with tables of moonrise and moonset. As such tables, in order to be at all accurate, must be computed for each locality, it is proper that the work should be done by the astronomers of the Nautical Almanac. But this is not always practicable and the tables given in the ordinary popular almanacs are not sufficiently accurate or extensive. A graphic method has just been published by Rev. W. F. Rigge, of Creighton University, Omaha, Nebr., (see Popular Astronomy, Vol. XIII, No. 10). This will enable any one to compute the times of rising and setting for a whole month or year in a short time, utilizing the data given in the Nautical Almanac. We, therefore, reprint the following article by Professor Rigge, in the conviction that many of our readers will make use of his method.—EDITOR.

[2] Page IV of the American Ephemeris and Nautical Almanac gives the following items in Greenwich mean time:

(1) The semidiameter of the moon at Greenwich mean noon and (2) at midnight.

(3) The horizontal parallax of the moon for Greenwich mean noon and (4) mean midnight, with (5) and (6) the rate of change of each in one hour.

(7) The Greenwich mean time of the upper transit of the moon's center across the meridian of Greenwich, and (8) the rate of change of this time for an hour, whence the time of transit over any other meridian can be computed.

(9) Finally the age of the moon at Greenwich mean noon, counting from the moment of conjunction with the sun.

The following are the figures for January 13, 1906:

(1) 15′ 44.9″, (2) 15′ 48.4″, (3) 57′ 42.0″, (4) 57′ 54.9″, (5) +1.11″, (6) +1.05″, (7) $14^h 58.4^m$, (8) 2.13^m, (9) 18.3 days.

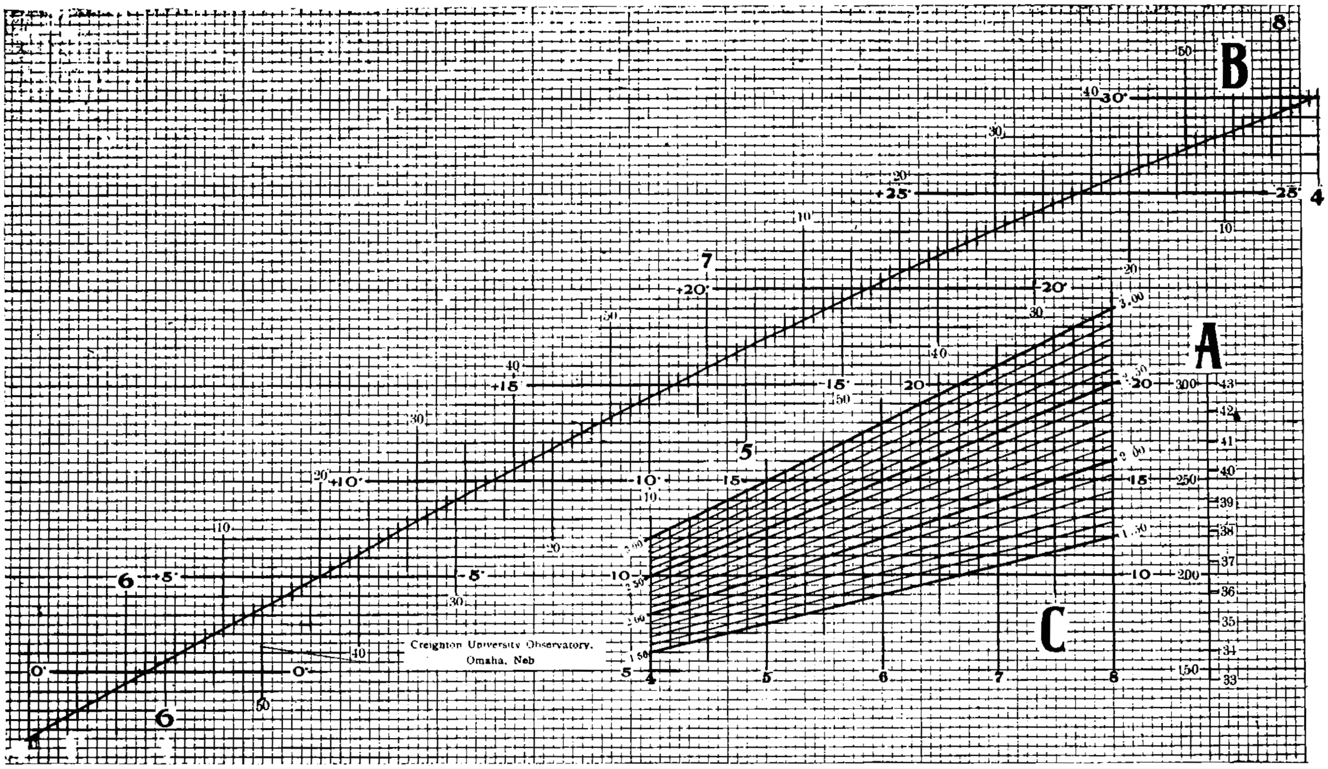

FIG. 1.—Rigge's method of finding the time of moonrise and moonset.

may always be used, since the extreme values differ only 3.7′ from it or less than one-fifteenth of its amount. As the parallax increases the hour angle while refraction diminishes it, the combined effect of both is to increase the moon's hour angle by two minutes. Accordingly all the hour angles on diagram B have been increased by this amount. No variations from the mean values of the refraction and parallax, used in the construction of this diagram, can ever change the hour angle one-third of a minute. No correction for semidiameter has been applied. This would diminish every hour angle at Omaha a minute and a half for the upper limb, or increase it as much for the lower. [Hence the computed times refer to the center of the moon.—EDITOR.]

Entering the Ephemeris[3] on pages V–XII of the month with the central time of the moon's meridian passage at Omaha increased by six hours (that is, the Greenwich time, $15^h\ 36^m + 6^h = 21^h\ 36^m$), on January 13, 1906, we find the moon's declination to be about $9\frac{3}{4}°$ north. I say "about," because at this stage the fraction of a degree is of no importance. With this argument of $9\frac{3}{4}°$ north, we find that on diagram B the moon's approximate hour angle is $6^h\ 37^m$. This is written under the time of the moon's transit, $15^h\ 36^m$, and then subtracted for rising but added for setting. With the results, $8^h\ 59^m$ and $22^h\ 13^m$, increased by six hours (to obtain the Greenwich times, $14^h\ 59^m$ and $28^h\ 13^m$) we make a second approximation and apply to the diagram the moon's declination at these times as found in the Ephemeris. We write down under $8^h\ 59^m$ and $22^h\ 13^m$ only the difference between the first and the second hour angles found on diagram B, viz, -4^m and -4^m in the present instance. Experience will soon show what fraction of a degree of the moon's declination it is necessary to take in order to get the hour angle correct to the minute. If any care at all has been taken about the first value of the moon's declination, the corrections -4^m and -4^m to the first approximate hour angle will agree numerically within two minutes, and will have the same sign, which will be plus when the moon is going north and minus when going south.

3. The third step is to correct the time of the moon's rising and setting for its motion in right ascension. This is done by means of diagram C, which is merely a graphic method of multiplication. The vertical lines marked 4, 5, 6, 7, 8, indicate the moon's hour angles, and the oblique ones 1.50, 2.00, 2.50, 3.00, the hourly difference of the times of the moon's meridian passage as given on page IV of the month in the Ephemeris. With these two as arguments, viz, $6^h\ 37^m$ and 2.13^m in the example selected, we find from the horizontal lines marked 5, 10, 15, 20, the correction sought, which here is fourteen minutes. This is to be subtracted for rising and added for setting, and is the same numerically for both.

As the correction given by diagram C may amount at times to twenty minutes and more, a third approximation would seem to be necessary. In declination this is inappreciable, since the maximum change of the moon's declination is less than one-third of a degree in an hour, and in twenty minutes it would never affect the moon's hour angle on diagram B to a noticeable fraction of a minute. In right ascension, however, a first correction of twenty minutes when added to the hour angle that was used to find it by means of diagram C would entail a second correction of a full minute if the hourly difference were 3.00, a limit which it never reaches. But as this second correction often exceeds half a minute, the hour angle may at once be increased by the amount of the first correction and another found from the diagram. It would not be advisable to reconstruct diagram C for the purpose of avoiding this additional labor, since, as will be said later, this error affects only the time of the moon's setting at Omaha, and never that of its rising.

4. Adding up our quantities algebraically, we obtain $8^h\ 41^m$ and $22^h\ 23^m$ as the astronomical central [standard] times of the moon's rising and setting at Omaha on January 13. Changing these to civil central [standard] times, we find that the moon

[3] Pages V–XII of the Ephemeris give the right ascension and declination of the moon for each hour of Greenwich mean time, astronomical reckoning, in which the zero hour corresponds to noon of the civil day of the same date.

rises on January 13 at 8:41 p. m. and sets on January 14, at 10:23 a. m. A day will be found to drop out for rising as well as for setting whenever the time changes from p. m. to a. m., viz, when it crosses midnight.

January 13, 1906.

Rising.	Setting.	
$15^h\ 36^m$	$15^h\ 36^m$	Meridian passage, central time, by A.
−6 37	+6 37	Approximate hour angle, by B.
8 59	22 13	Approximate times.
− 4	− 4	Correction for change of declination, by B.
−14	+14	Correction for change of right ascension, by C.
8 41	22 23	Astronomical central [standard] times.
13^d 8:41 p. m.	14^d 10:23 a. m.	Civil central [standard] times.
$8^h\ 40^m\ 39^s$	$10^h\ 21^m\ 59^s$	Numerical computation as check.

Accuracy.—The diagrams, especially A and C, may be used to tenths of a minute, if desired. But the nearest whole minute is sufficiently accurate in practise, since often the horizon is obstructed by terrestrial objects or dimmed by smoke, or the weather is unpropitious, and most of the times of moonrise and moonset occur during the daytime or at inconvenient hours during the night, so that only such a small percentage of the computed times are actually observed that more accurate and time-consuming computation would seem to be only so much labor wasted. As three diagrams are used, and the nearest minute is taken in each one, it may happen that in each case nearly half a minute is neglected always in the same direction, and, therefore, the results may be erroneous by more than a full minute. This is certainly possible and must occur at times, but it is just as likely that these fractions of a minute may have contrary signs and annul one another.

No account need ever be taken of second differences in the times of the moon's meridian passage. For Omaha the moon always rises within two hours and a quarter of its upper transit at Greenwich, so that the errors of these diagrams A and C counteract one another. But as the time of the moon's setting occurs within two hours and a quarter of the moon's lower transit the errors of these diagrams are additive. An examination of the Ephemeris of 1894, when the moon's ascending node was near the vernal equinox and the moon, therefore, reached a declination of over 28°, showed the maximum second difference between two successive days to be 0.24 minute. For an interval as great as sixteen hours from the time of the moon's upper transit at Greenwich, only one-third of this, or 0.08, would be effective, and this amount for the maximum hour angle (eight hours) would be only about 1.2 minute. As this is a most exceptional case, it is safe to say that, in general, this method is accurate enough to give the times within a minute. This estimate was confirmed by a more rigorous numerical computation of this same example of January 13, 1906, which was selected at random, and in which the moon's right ascension and declination, the sidereal time, and other necessary quantities were used and the same result was obtained practically within a minute.

Speed.—The speed is such that I generally compute the times of both rising and setting for a whole month in less than an hour, and sometimes even in less than 45 minutes.

A POSSIBLE EXTENSION OF THE PERIOD OF WEATHER FORECASTS.

By E. B. GARRIOTT, Professor of Meteorology. Dated February 15, 1906.

Periods of excessive heat or cold, and of drought or stress of rain, are invariably associated with marked irregularities in the location and movement or in the character and intensity of the great continental and oceanic areas of high and low barometric pressure. During periods of abnormal heat or drought in any part of the Northern Hemisphere, there is an undue and stagnated accumulation of air in and about one of the great anticyclonic areas, and a corresponding deficiency in and about one of the great cyclonic areas. Periods of cold or of excessive precipitation are due either to (1) abnormally rapid changes in the greater atmospheric areas, whereby a rapid progression of the lesser areas of high and low barometer produces a succession of cold waves and rains, or to (2) a persistent abnormal distribution or development of one or more of the greater areas whereby existing conditions of cold, or of wet, are prolonged. It is also true that abnormalities of weather over some portions of the globe, or of the Northern Hemisphere, are counterbalanced by opposite tendencies over other portions. Thus months that are exceptionally warm or cold, wet or dry, over the United States east of the Rocky Mountains have similar characteristics over Europe and at least a part of western Asia, and exhibit opposite tendencies over the United States west of the Rocky Mountains and over southeastern Asia. An explanation of this fact is found in a study of the greater areas of high and low barometric pressure or "centers of action" of the Northern Hemisphere.

These "centers of action" appear to control the character and movements of the areas of high and low barometer that appear on our daily weather maps, and in efforts to coordinate the causes that contribute to produce weather effects in the hemisphere as a whole or in any of its parts, all causes are important and none can be neglected. Professor Hann has found that pressure changes in the Azores high area and the Iceland low area are interrelated and of an opposite character, and that these changes are associated with certain phases of weather in central and northwestern Europe. He has discovered that rising barometer over the Azores is usually attended by falling barometer over Iceland, and, *vice versa*, that falling barometer in the Azores high area is attended by rising barometer in the Iceland low area. Also that falling barometer in the Iceland area produces warmer weather over central and northwestern Europe, and that rising barometer over Iceland is followed by falling temperature over northwestern Europe. It appears, therefore, that marked changes in the Azores high area, regarding which advices are cabled daily, afford an index of the character of the weather that will prevail for several days over a considerable portion of Europe.

A merely preliminary and general consideration of the whole problem places the dominating centers of atmospheric action of the Northern Hemisphere over Siberia and Bering Sea, and an examination of these areas presents an interrelation similar to that noted for the north Atlantic high and low areas. It has been observed, furthermore, that the effects of changes in the Asiatic high and the Bering Sea low are vastly greater and more widespread than those that may be associated with the north Atlantic areas, and that when pressure abnormalities within and about the Asiatic-Bering centers of action are marked, persistent and well-defined types of abnormal weather are experienced throughout the circuit of the Northern Hemisphere.

Among well-remembered abnormal seasons, or parts of seasons, when the influence of the dominating "centers of atmospheric action" was conspicuous, were the mild months of the winters of 1889–90 and 1905–6, and the cold months of the winters of 1903–4 and 1904–5. The months of the winters of 1889–90 and 1905–6 that were warm over great portions of the United States and Europe showed an unusual depression in the Bering Sea low area. The deepened Bering Sea area extended and overlapped the northwestern part of North America, and offshoots therefrom moved eastward in abnormally high latitudes. The resultant abnormal depression of the barometer over northwestern British America caused an unusual prevalence of southerly winds over northern portions of the United States and apparently prevented the formation of the areas of high barometer over British America that are essential to the origin and propagation of American cold waves.